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ABSTRACT

Age differences in intellect as reflected by performance on the Wechsler Adult Intelligence Scale (Revised) (WAIS-R) were evaluated for persons aged 20 to 74 years. Educational attainment levels were held constant. The WAIS-R sample included 1,480 men and women in the following seven age groups--20-24 years (n=250), 25-34 years (n=250), 35-44 years (n=250), 45-54 years (n=250), 55-64 years (n=160), 65-69 years (n=160), and 70-74 years (n=160). The 25-34 year age group served as the target sample for this study; the mean scores for adults in each educational category, within each age group, were weighted to match the educational distribution of ages 25-34 years. After weighting for education, the decline in verbal intelligence quotient (IQ) from age to age disappeared. However, declines across the 20-74 year range remained for performance IQ and full scale IQ, even after controlling for education. These results were also obtained using multiple regression techniques. The impact of education on each of the 11 subtests was also evaluated; the results were interpreted as supportive of J. L. Horn's fluid-crystallized explanation of changes in intelligence with advancing age. Seven data tables and 14 graphs are included. (TJH)

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What Role Does Formal Education Play in the IQ-Age Relationship Across the Adult Life-Span?

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Abstract

Age differences in intellect as reflected in WAIS-R performance from age 20 to 74 years were evaluated while educational attainment levels were held constant. The seven adult age groups (ranging from 20-24 to 70-74) in the WAIS-R standardization sample, comprising a sample of 1480 men and women, provided the data source. The 25-34 year age group served as the target sample for this study; the mean scores for adults in each educational category, within each age group, were weighted to match the educational distribution of ages 25-34. After weighting for education, the decline in mean Verbal IQ from age to age disappeared. However, declines across the 20-74 year range remained for Performance IQ and Full Scale IQ, even after controlling for education. These results were also obtained using multiple regression techniques. The impact of education on each of the 11 subtests was also evaluated; the results were interpreted as supportive of Horn's fluid-crystallized explanation of changes in intelligence with advancing age.

What Role Does Education Play in the IQ-Age Relationship Across the Adult Life-Span?

The alleged decline of intelligence from young adulthood and middle age to old age has been the subject of considerable research (Birren & Schaie, 1985; Kausler, 1982) and much controversy (Baltes & Schaie, 1976; Botwinick, 1977; Horn & Donaldson, 1976). The advantages and disadvantages of cross-sectional, longitudinal, and other experimental methodologies have been dissected and expounded (Kausler, 1982; Nesselroade & Labouvie, 1985); the possibility of anyone designing and conducting a definitive experiment seems remote, since each type of study brings with it built-in problems that affect internal validity, external validity, or both. For example, longitudinal studies, though in some ways superior to cross-sectional investigations, are beset by threats to validity such as practice effects, unsystematic attrition, and questionable generalizability of findings to individuals born in subsequent decades. Nevertheless, each investigation that has been conducted over the past half-century or so has contributed to the understanding of changes in intellectual abilities across the adult age range.

The availability of cross-sectional data on a large, representative sample of adults spanning the broad 20 to 74 year range (i.e., the standardization sample of the Wechsler Adult Intelligence Scale--Revised or WAIS-R; Wechsler, 1981) impelled the design of this study. However, this endeavor was undertaken with awareness of the limitations of cross-sectional investigations, most notably the inability to control for cohort differences,

i.e., generational differences that impact on the intellectual development of virtually anyone growing up in a particular generation. Since one basic difference among various 20th century cohorts is their level of educational attainment, the variable of education was controlled in this study. Based on the available data, it was possible neither to identify nor control any other cohort differences presumably characterizing the seven age groups that constituted the 20 to 74 year old sample.

One goal of this study was to evaluate the existence of what Botwinick (1977) has termed the classic intellectual aging pattern, based on his review of numerous cross-sectional and longitudinal investigations: maintenance of nonspeeded intellectual performance, even through the 70s, contrasted with a much earlier decline in speeded tasks. The investigation also sought to evaluate Horn's (1978) alternative interpretation of the classic intellectual aging pattern from the vantage point of the fluid-crystallized theory of intelligence. According to Horn, crystallized intelligence, as a function of accumulating cultural knowledge throughout a lifetime, tends to increase across the adult years; fluid intelligence, more associated with new problem solving and incidental learning and directly correlated with physiological functioning and neurological integrity, declines throughout adulthood.

An additional goal of this study was to relate WAIS-R data obtained in the 1970s with similar data obtained in the 1950s on the WAIS (Wechsler, 1955) by Birren and Morrison (1961) and in the 1960s on the Spanish version of the WAIS (Green, 1969). Unquestionably, the most outstanding series of research studies on intelligence and aging has been the exhaustive longitudinal and

cohort-sequential investigations conducted by Schaie (1983) and his colleagues (Schaie & Hertzog, 1983; Schaie & Labouvie-Vief, 1974; Schaie & Strother, 1968). However, these studies used the Primary Mental Abilities Test (Thurstone & Thurstone, 1949), a test of high speed and low power (Dixon, Kramer, & Baltes, 1985) that is group administered. The age-intelligence patterns observed by Schaie and his colleagues--generally little decline prior to age 60, but clear decrements in performance on all PMA subtests (verbal and nonverbal) after age 60--may not generalize to patterns on the individually administered WAIS-R Verbal and Performance Scales; hence, any age-intelligence patterns observed in the present study are not directly comparable to Schaie's findings because of instrument differences (as well as differences in experimental design), but can be compared readily to the work of Green (1969) and Birren and Morrison (1961). Nevertheless, one of Schaie's key findings from his several investigations was kept fully in mind when interpreting the present cross-sectional results: "that cohort differences exert profound effects in observed patterns of intellectual development in adulthood" (Dixon et al., 1985, p. 318).

Birren and Morrison (1961) evaluated the relationship of age to scores on each of the 11 WAIS subtests, across the 25 to 64 year range, by using correlational and principal components analysis. Correlations were negative between age and scores on each of the 11 subtests, indicating that there was a tendency for younger adults to outperform older adults in each subskill assessed by the WAIS. The tendency was considerably less for Verbal subtests (*r*s ranged from -.02 to -.19) than for Performance subtests (*r*s of -.28 to -

.46). When education was partialled out of the correlations, the coefficients between age and Performance subtest scores remained negative and statistically significant (*r*s of -.16 for Picture Completion to -.38 for Digit Symbol); however, four of the six partial correlations between age and Verbal subtest scores became positive, with values of .22 and .17 observed for Vocabulary and Information, respectively.

Birren and Morrison's (1961) principal components analysis of the 11 subtests and age (with education partialled) showed that age loaded trivially (-.06) on the first unrotated factor (interpreted as g), but had the highest loading (.59) on the second unrotated factor, a bipolar dimension featuring positive loadings by most Verbal subtests and negative loadings by all Performance tasks. This factor, which has since been interpreted as a learning disabilities index or laterality index of cognitive impairment (Lawson, Inglis, & Stroud, 1983; Tittemore, Lawson, & Inglis, 1985), was considered to be an aging component by Birren and Morrison (1961). They interpreted the highest positive loading by Vocabulary (.34) and the highest negative loading by Digit Symbol (-.36) as support for their hypothesis of the "incremental and decremental processes of aging" (Birren & Morrison, 1961, p. 367). In essence, this bipolar factor corresponds to the "classic intellectual aging pattern," whether interpreted from Botwinick's (1977) or Horn's (1978) perspective.

By partialling education from the correlations, Birren and Morrison (1961) attempted to control for striking differences in the educational level of different age groups in the WAIS standardization sample. For example, only

10% of the 55-64 year olds in Birren and Morrison's sample had 13 or more years of schooling compared with 33% of their 35-44 year olds. Indeed, controlling for education reversed the sign of the correlation with age for several verbal subtests. Quite evidently, the steadily decreasing sums of scaled scores on the WAIS across the adult age groups, interpreted by Wechsler (1958) as evidence of a decline in intellectual function with advancing age, was due (at least on the Verbal Scale) to educational differences in the cohorts.

Green (1969), disturbed by interpretations (such as Wechsler's) of loss of intelligence during the aging process, conducted the "most careful study thus far of education-related effects on patterns of intellectual aging" (Labouvie-Vief, 1985, p. 515). Green (1969) helped standardize the Spanish WAIS in Puerto Rico, and observed the same striking decrements in test performance on the Spanish WAIS from age group to age group that has been noted on the American WAIS. However, he then compared WAIS performance from age to age for groups that he equated on educational level by selectively discarding cases from the sample until ages 25-29, 35-39, 45-49, and 55-64 were "balanced." He found <u>increases</u> in Verbal sums of scaled scores across the 25-64 year range and little decline on the Performance scale. Green (1969) generalized considerably from his Spanish data, stating that "intelligence as measured by the WAIS does not decline . . . before age 65" (p. 626). Yet Green's (1969) samples had relatively low levels of education, equated at slightly less than 8 years of schooling. Whether or not his findings on the Spanish WAIS generalize to more educated samples remains to be

determined; certainly his finding of virtually no decline in Performance IQ with age was not supported by Birren and Morrison's (1961) analyses of WAIS data.

The present study aimed to address the same general question researched by Birren and Morrison (1961) and Green (1969): How much of a decline in mean WAIS-R intelligence test scores, across seven age groups in the 20-74 year range, will still remain after equating all age groups for educational level? This investigation used two statistical procedures to answer the questions that were posed: Multiple regression, a methodology akin to Green's (1969) that created groups balanced on education. Additionally, data for the three WAIS-R IQs and the 11 separate subtests were analyzed by both procedures, with the hope that the patterns on these 14 variables might offer insight into the Botwinick (1977) versus the Horn (1978) interpretation of changes in intellectual function with age.

Method

Subjects

Adults in the WAIS-R standardization sample (N = 1480) constituted the subjects for this study. The following seven age groups were studied: 20-24 years (N = 250), 25-34 years (N =250), 35-44 years (N = 250), 45-54 years (N = 250), 55-64 years (N = 160), 65-69 years (N = 160), and 70-74 years (N = 160). Each age group was stratified on U.S. Census data on the variables of sex, race, geographic region, urban-rural residence, educational level, and occupation. More detail on the sample is given by Wechsler (1981).

The 400 adolescents in the WAIS-R sample, ages 16-19, were excluded from this study. Since many individuals in the 16-17 and 18-19 year samples had not yet completed their educations and, indeed, were generally too young to be college graduates, it was not feasible to equate them on educational attainment with the adult samples; their level of responding is also far less central to the primary question raised in the study and the various controversies in the literature.

Procedure

Table 1 summarizes data from the WAIS-R manual (Wechsler, 1981, Tables 5 and 7) that show both the plunging sums of scaled

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Insert Table 1 about here

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scores on the three IQ scales (especially Performance) across the adult age range, and the very different proportions of adults in different educational categories for each age group. Since scaled scores on the subtests for every age group are based on a single reference group of 500 adults ages 20-34 years, the sums of scaled scores shown in Table 1 are derived from a common yardstick, permitting direct comparison of test performance from age group to age group. However, the comparison is obscured by the different educational levels achieved by each age group. The percent with 11 or fewer years of schooling increases from 17 to 60 from ages 20-24 to 70-74, whereas the percents of high school graduates and adults with 13 or more years of schooling decrease steadily from age to age. Since the age groups with more education (i.e., the younger adults) are also the ones earning the highest

sums of scaled scores, one cannot be sure whether the declining sums of scaled scores, particularly above age 34, are more due to increasing age or decreasing education.

Two statistical methods were used to address this question. The first procedure was multiple regression; age level, both with and without a control for education level, was used to predict each of the three WAIS-R IQs and the 11 scaled scores. The seven age levels included in this study were coded 1 (ages 20-24) through 7 (ages 70-74). Education was coded as follows: 1 = 0-7 years of schooling; 2 = 8 years; 3 = 9-11 years; 4 = 12 years; 5 = 13-15 years; 6 = 16+ years. To control for education, education level was entered first into each analysis, followed by age. Age was considered to contribute significantly to each prediction of a WAIS-R variable if it met two criteria: (a) significant F at .01 level, and (b) addition of at least 2 percent variance over and above the percent accounted for by education alone. Regression equations were also conducted with age entered as the only predictor to see the relationship of age to intelligence prior to a control for education. Again, R^2 had to be significant at the .01 level and account for at least 2 percent of the variance in intelligence scores. In these analyses, the .01 level was chosen because of the large number of regression equations (14 with just age as a predictor, 14 with education controlled). The 2 percent criterion was used to ensure that any relationship was meaningful, not just statistically significant; with a sample size of 1480, even tiny R^2 values or increments in R^2 can be significant.

The second analysis that was conducted aimed to create different age groups that were equated on education. To accomplish this goal, mean sums of scaled scores on the Verbal, Performance, and Full Scales were computed, separately by age group, for adults having the following number of years of schooling: 0-8, 9-11, 12, 13-15, 16+. Then, within each age group, these means were weighted by the proportion of adults in each of the five educational categories at ages 25-34, designated as the target or yardstick age group for this study. In the WAIS-R sample, the following proportions of adults were in each educational category at ages 25-34, and were therefore used as weights for every age group: 0-8 years (.053), 9-11 years (.117), 12 years (.393), 13-15 years (.200), 16+ years (.237). The weighted means for the Verbal, Performance, and Full Scale sums of scaled scores allow comparison of test performance from age group to age group with years of schooling held constant.

Since sums of scaled scores are not units that are comparable from scale to scale, and are not readily understood or used by professionals, all sums of scaled scores were converted to IQs. This conversion was made by using the IQ table for 25-34 year olds for every age level. This choice was sensible since that age group was used to equate all seven age groups on educational background. For each age group, the mean sums of scaled scores (Verbal, Performance, Full Scale) shown in Table 1--i.e., the actual mean scores earned by the samples--were entered into the IQ conversion table for ages 25-34, and the corresponding IQs (to the nearest tenth of a point) were obtained. Then this procedure was repeated using the weighted or adjusted sums of scaled

scores, to determine the corresponding IQs when education is controlled. Next, the IQ that was uncontrolled for education was subtracted from the weighted or controlled IQ to compute the IQ change attributable to level of education.

These differences were then evaluated for statistical significance using a dependent *t* with a Bonferroni correction for multiple comparisons. Actual computations were based on the sums of scaled scores, for which *SD*s were available, rather than on the converted IQ values. Statistical significance was also determined for the pattern of mean sums of scaled scores earned by each of the seven age groups on the three IQ scales, both with and without a control for education. For each scale (Verbal, Performance, Full), two univariate ANOVAs with age as the independent variable were conducted--one with the actual sum of scaled scores as dependent variable, and the other with the weighted sum of scaled scores (i.e., controlled for education) as the dependent variable. Following each of the six ANOVAs, Tukey Honestly Significant Difference (HSD) tests were conducted to evaluate the significance of the difference between all possible pairs of mean scores.

After using the equating procedure to analyze Verbal, Performance, and Full Scale IQs, the weighting procedure was repeated for each of the 11 WAIS-R subtests to determine the impact of educational level on subtest performance for each of the seven age groups. Unlike the IQ analyses, the subtest scores did not need to be converted to another metric because: (a) scaled scores are readily understood by professionals, and (b) scaled scores are already

directly comparable from age to age (in a developmental sense), since they are obtained from data on a single reference group of 20-34 year olds.

Results

Multiple Regression Analysis

Table 2 summarizes the results of the multiple regression

Insert Table 2 about here

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analyses, both with and without a control for education. When chronological age is entered as the only predictor of the three WAIS-R IQs and 11 subtests, all values of R^2 produced F's that were significant at $p < .001$. However, the values of R^2 for Information, Vocabulary, Arithmetic, and Comprehension accounted for less than 2 percent of the variance, and were therefore interpreted as "not meaningful." Verbal IQ and Digit Span barely exceeded the 2 percent criterion, whereas age accounted for nearly 30% of the variance in Performance IQ and Digit Symbol.

When education is entered as the first variable in the regressions, and age as the second, only Performance IQ, all five Performance subtests, and Full Scale IQ (barely) meet both criteria: significant F for the increment due to age and accounting for at least 2 percent of additional variance. Verbal IQ and four Verbal subtests (Digit Span, Arithmetic, Comprehen-sion, Similarities) showed less than a 1 percent increment in R^2 when age was added to education as joint predictor.

The multiple regression analyses show that Performance IQ and each separate Performance subtest are significantly and substantially related to

age, even after controlling for education. In contrast, neither Verbal IQ nor any Verbal subtest is meaningfully related to age after controlling for years of schooling.

Table 2 also presents R^2 for education when it is entered as the sole predictor of intelligence. These values are higher (for Verbal variables, strikingly higher) than the R^2's obtained when age is the sole predictor for the three WAIS-R IQs and for all subtests except Object Assembly and Digit Symbol.

Analysis with Equated Groups

Verbal, Performance and Full Scale IQs. Table 3 presents mean Verbal, Performance, and Full Scale sums of scaled scores for

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Insert Table 3 about here

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each age group separately by educational level; it also shows the Verbal, Performance, and Full Scale weighted means, i.e., values adjusted for educational level.

The results are quite revealing and consistent with the findings in the regression analyses. For the Verbal Scale, the mean sums of scaled scores for a given educational level are remarkably similar from age to age. Basically, those with 0-8 years of schooling earned a Verbal sum of about 40; those with 9-11 years scored about 50; high school graduates scored 55-60; those with some college scored about 65; and college graduates scored 70-75. The occasional exception to the above general finding may have been due to chance

(e.g., the value of only 31.9 for 25-34 year olds with 0-8 years of schooling was based on a sample of only 16).

For the Performance Scale, the means were not similar for the different educational categories across the age range. Rather, within each level of educational attainment, the means tended to drop with increasing age; largest decrements occurred above age 64. The only exception to this pattern was at 0-8 years of schooling, where the means still decreased from age to age, but only slightly.

Table 4 converts the actual and weighted mean sums of scaled

Insert Table 4 about here

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scores in Tables 1 and 3 to IQs, using the norms table for 25-34 year olds as a common yardstick; the table also shows the change in IQ, for each age group, that may be attributed to educational differences in the samples.

Table 4 reveals that within each age group the mean IQ increases on the Verbal, Performance, and Full Scales after correcting for educational level (except at ages 25-34, the target group, for which no increase is possible). Whereas the gains at ages 20-24 and 34-44 did not reach statistical significance, all four age groups between 45-54 and 70-74 showed significant positive changes on the Verbal and Full Scales after controlling for educational level. On the Performance Scale, however, IQ gains were smaller and reached significance only for ages 55-64 and 65-69.

More interesting than which differences were significant after controlling for education are the patterns of mean IQs from age to age on the

three IQ scales. These patterns reinforce, and enhance, the findings from the multiple regression analyses. Before controlling for education, mean Verbal IQs increased from 95.6 at ages 20-24 to 98.4 at ages 25-34 and then descended fairly steadily to a mean of only 89.5 at ages 70-74. (Remember that the decrease in Verbal IQ is only because norms for 25-34 year olds were used in this study for all ages as a means of comparing the age groups. In actuality, WAIS-R IQs for each age group are normed separately to produce means of 100 and SDs of 15.) As happened in the regression analysis, this apparent drop in Verbal IQ with increasing age essentially disappears when differences in educational level are controlled. Means for all age groups ranged from 96.5 to 99.8 when education is equated. The highest value was obtained for ages 55-64, and even though slight decrements in Verbal IQ were observed above age 64, the values for ages 65-69 and 70-74 still exceed the mean IQ for ages 20-24. The relationship of Verbal IQ to age, with and without a control for education, is depicted in Figure 1.

Insert Figure 1 about here

On the Performance Scale, mean IQs plunged steadily with age from 101.1 at ages 20-24 to 75.6 at ages 70-74, when education is uncontrolled. Even after controlling for educational level, Performance IQ still reduces steadily and dramatically with age, from 101.8 at ages 20-24 to 78.7 at ages 70-74; again, a drop of 1 1/2 SDs is evident. Figure 2 displays these findings graphically, reiterating the results of the regression analysis.

Insert Figure 2 about here

Hence, the data for Verbal and Performance IQs in both the regres-sion and equating analyses support Botwinick's (1977) classic intellectual aging pattern when educational level is controlled.

The findings for Full Scale IQ reflect a combination of the very different results for Verbal and Performance IQ (see Table 3 and Figure 3). Without a control for education, Full Scale IQ

Insert Figure 3 about here

decreases by about 1 SD across the age range. After appropriate controls are made, a drop of about 2/3 SD is evident. However, the lowering of Full Scale IQ is gradual from ages 20-24 (mean = 98.8) through ages 55-64 (mean = 94.8), and only becomes substantial at ages 65 and above.

ANOVAs conducted on the Verbal, Performance, and Full Scales revealed that the mean sums of scaled scores differed significantly for the seven age groups on all three scales before equating for education, producing the following F values: Verbal ($F = 8.246$, $p < .001$), Performance ($F = 78.846$, $p < .001$), Full Scale ($F = 31.556$, $p < .001$). After equating for education, the weighted Verbal mean sums of scaled scores did not differ significantly ($F = 1.245$, $p > .05$); however, the ANOVAs still produced a significant age main effect for the performance Scale ($F = 56.823$, $p < .001$) and Full Scale ($F = 11.578$, $p < .001$). These ANOVAs replicated the results of the multiple regression analyses.

Table 5 summarizes the results of the Tukey HSD tests for the five ANOVAs that produced significant F values for the main

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Insert Table 5 about here

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effects of age. As is evident from this table, Verbal, Performance, and Full Scale IQs decline with age with the exception of Verbal IQ when controlled for education. Generally, differences spanning three or more age groups tend to be statistically significant whereas differences spanning fewer than three age groups tend to be nonsignificant.

The Eleven Subtests. Table 6 provides data for the six

Insert Table 6 about here

Verbal subtests, showing mean scaled scores for each age group, both with and without a control for education. Data for the four most achievement-oriented subtests (Information, Vocabulary, Arithmetic, Comprehension) mirror the data for the Verbal Scale as a whole, a finding that also occurred in the multiple regression analyses (see Table 2). Despite decreases in mean scores, usually after age 34, when education is uncontrolled, the means for these four subtests tend to increase slightly with age when educational level is equated; even at ages 70-74, the weighted means are never lower than at the target age of 25-34. Digit Span and Similarities, tests of verbal ability that demand little knowledge of specific facts, behave differently. Mean scores controlled for education do not increase after age 34, and the means for ages 65-69 and 70-74 are decidedly less than for ages 25-34.

Corresponding analyses for the five WAIS-R Performance subtests are presented in Table 7. Data for all tasks resemble

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Insert Table 7 about here

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the findings described previously for Performance IQ, and mirror the results of the multiple regression analyses. Education-controlled mean scaled scores are highest on each subtest for age 20-24, and decrease at the rate of about 1/2 scaled-score point per age group for each subtest except Digit Symbol. For Digit Symbol, the plunge is more dramatic, decreasing by 1 scaled-score point per age group starting with ages 45-54. The drop from ages 20-24 to ages 70-74 is about 1 SD (3 scaled-score points) for Picture Completion, Picture Arrangement, Block Design, and Object Assembly; for Digit Symbol the drop is 1 2/3 SD.

Figures 4 and 5 display mean changes from age to age on each of the 11 subtests, both with and without a control for education.

Insert Figures 4 and 5 about here

Discussion

Relationship to Previous Findings of Green and Birren and Morrison

The present WAIS-R results are extremely consistent with the WAIS findings reported by Birren and Morrison (1961) for white adults between 25 and 64 years of age. They found negative correlations with age for all 11 subtests, with the largest coefficients occurring for the five Performance

tasks. After partialling out education, they found that four correlations became slightly positive (.08 - .22), indicating some improvement with age; these four subtests all from the Verbal Scale. Birren and Morrison (1961) also reported significant negative partial correlations with all five Performance subtests, with the highest values obtained for Digit Symbol (-.38) and Picture Arrangement (-.27). Similarly, in the present analysis, Digit Symbol showed the largest increment in R^2 (14.4%) of any WAIS-R variable in the multiple regression analysis when age was added to education as a predictor, and Picture Arrangement also evidenced a substantial (7.9%) increment.

In contrast, the present results do not accord well with Green's (1969) findings. Green reported increases in verbal intelligence from the late 20s to the late 30s, and additional increases to the 40s before a virtual flattening out of the curve for 55-64 year olds. Whereas he did not observe increases in Performance scores after age 39 for his education-matched age groups, the decrements he did note through age 64 were minor--indeed trivial--compared to the huge declines in Performance IQ evident in the present WAIS-R data. Although Green's (1969) study is widely cited in the literature (e.g., Kausler, 1982; Labouvie-Vief, 1985; Matarazzo, 1972), the limited generalizability of the findings due to the low level of education of Green's sample is not often mentioned. Yet it seems that Green's results may be largely related to the fact that his sample averaged less than 8 years of schooling.

Examination of Table 3 supports this contention. The mean sum of Verbal scaled scores for individuals with 0-8 years of schooling was only 31.9 for ages 25-34, but rose to 37.3 for ages 35-44 and to about 42 for ages 45-64. (Adults below age 25 and above age 64 were not included in Green's study, so data for those age groups are not pertinent here.) That pattern was precisely the pattern observed by Green for his sample. Yet, that trend did not hold for 9-11 years of schooling, high school graduates, and so on, for the present, more heterogeneous sample. Hence, the increases in verbal intelligence, with education controlled, reported by Green (1969) was not observed in the WAIS-R study for the total sample, or for any educational category except 0-8 years--the category most resembling Green's total sample.

Similarly, Table 3 reveals mean sums of scaled scores on the Performance Scale that drop only slightly from ages 25-29 (Mean = 33.1) to 55-64 (Mean = 28.9) for individuals with 0-8 years of schooling. Again, this finding mirrors Green's (1969) results, but it is not generalizable to the results for the present total sample, or for the separate educational categories from 9-11 to 16+ years of schooling, all of which showed large decreases in mean scores from ages 25-34 to 55-64.

Certainly the differences between the present findings and Green's (1969) results may be due to numerous factors including cohort differences. instrument differences (WAIS vs. WAIS-R), and language-cultural differences (Spanish/Puerto Rican vs. English/American). However, the fact that the present data for the lowest educational level parallel Green's (1969) findings so closely suggests that he might have obtained very different results with

the Spanish WAIS in the 1960s if it had been appropriate or possible for him to include in his study sizable proportions of adults with considerably more schooling than 8 years.

The Classic Intellectual Aging Pattern

The WAIS-R Verbal Scale includes all untimed tasks (except for Arithmetic), whereas the Performance Scale comprises all timed subtests, including the highly speeded Digit Symbol subtest and two tasks which allot bonus points for rapid perfect performance (Block Design, Object Assembly). Hence, the general pattern of essentially no change in Verbal IQ across the 20-74 year range after controlling for education, coupled with a steep decline in Performance IQ across the age span, is certainly congruent with Botwinick's interpretation of the classic intellectual aging pattern: maintenance of performance on nonspeeded tasks versus declining performance on speeded tasks. However, since most Verbal subtests measure crystallized intelligence and all Performance tasks are reasonably good measures of fluid ability, the present results also adhere to Horn's (1978) interpretation of the classic aging pattern from the fluid-crystallized theory of intelligence.

Examination of the mean scores across the adult age range on the 11 separate subtests adds some insight into the two different interpretations of the classic pattern. As stated previously, the four Verbal subtests for which performance was maintained through the 70s (when education was controlled) are the ones most dependent on school learning, i.e., prototypical measures of crystallized intelligence. This group includes Arithmetic, a speeded test (15-30 seconds are allotted for the first nine items, 60-120 seconds are

allotted for the remaining five items) that awards one bonus point for very rapid correct responses on each of the five most difficult items.

The two Verbal subtests that showed lower mean scores for the older age groups, even after equating for education, were Similarities and Digit Span. Digit Span is a measure of fluid intelligence to some extent, and Similarities has several attributes that resemble fluid tests: (a) all of the concepts, even for hard items, are well known to virtually all adults (e.g., work-play, fly-tree); (b) the nature of the commonalities between the pairs of concepts (e.g., living things) are widely known to virtually everyone; and (c) correct responses depend far more on abstract thinking and problem solving ability than on crystallized learning.

Certainly, the declines in Similarities and Digit Span are mild compared to the early and rapid decrease in scores with increasing age group for all five Performance subtests, especially the highly speeded Digit Symbol task. Probably noncognitive variables such as health status (Botwinick & Birren, 1963), motor coordination, visual perception, and reflectiveness join with fluid ability and speed of problem solving in producing the declines on the Performance Scale. However, data for the speeded Arithmetic subtest, and the speeded Performance tasks suggest that the classic intellectual aging pattern identified in this study may be interpreted more readily from a Horn (1978) fluid-crystallized approach than from a Botwinick (1977) speeded-nonspeeded explanation. Also consistent with Horn's theorizing is the higher scores earned by ages 20-24 than by ages 25-34 on the Performance (but not the Verbal) Scale. Finally, note in Table 7 and Figure 5 that the age-by-age

means for Picture Completion and Picture Arrangement resemble closely the values for Block Design and Object Assembly. Yet the first pair of WAIS-R subtests offer no bonus points, whereas the latter pair include numerous bonus points (up to 3 on most items) for very rapid perfect performance. If the Performance IQ decline with age is primarily a function of the speed dimension, due to decreasing motor coordination and/or increasing reflectiveness, one would have anticipated much steeper declines in Performance IQ with advancing age for those Performance subtests that allot bonus points for speed.

Nonetheless, the present interpretation of the data from a fluid-crystallized theory perspective must retain tentative until alternative explanations related to cohort differences--as well as developmental changes in motor coordination, reflectiveness, physical health, and so forth--can be ruled out by further, well controlled, research studies. In addition, fluid-crystallized interpretations of the aging process are best made from tasks specifically built to assess these theoretical abilities rather than from tasks (like WAIS-R subtests) that are factorially complex and are "bent" to fit the theoretical model.

Conclusions

1. When education was uncontrolled, test scores showed a steady decline on the WAIS-R Performance Scale after age 24 and on the WAIS-R Verbal and Full Scales after age 34. The decline was far greater for the Performance than Verbal scale, although age was a significant predictor of all three IQs in the regression analysis.

2. When education was controlled in both types of analyses, the decline in Verbal IQ disappeared, but remained for Performance and Full Scale IQs, thus revealing what Botwinick (1977) has termed the classic intellectual aging pattern.

3. After controlling for education in the "equated groups" analysis, performance on Information, Vocabulary, and Comprehension tended to increase across the adult age range, and performance on Arithmetic was maintained. In contrast, test scores declined on Similarities and Digit Span for the older age groups, and scores declined across the entire age range for each Performance subtest. Digit Symbol, the most highly speeded of Wechsler's Performance tasks, showed the greatest decline. However, previous research has shown that age differences on Digit Symbol are not merely due to speed of responding (Storandt, 1976). The best explanation for the aging pattern found in the present study is probably Horn's (1978) distinction between fluid and crystallized intelligence; he posits improvement in crystallized abilities with increasing age, accompanied by loss of functioning in fluid abilities starting in late adolescence. Botwinick's (1977) hypothesis of maintenance of performance on nonspeeded tasks across the adult age range, coupled with decreasing scores on speeded tasks--though generally consistent with the WAIS-R data--does not seem to explain the observed patterns as well as Horn's (1978) theoretical approach.

4. Despite the very different age changes for the Verbal and Performance Scales when education was controlled, the results must be interpreted in the context of other cross-sectional studies, with awareness that the lack of

longitudinal data for any of the subjects in the sample limits any interpretation of developmental phenomena. In this study educational attainment was controlled, but Matarazzo (1972) and others have noted that 12 years of schooling, for example, may mean different things for a 65 year old and a 25 year old. Furthermore, it was not possible to control other variables on which the cohorts might have differed substantially, and which might have affected WAIS-R test performance, for example, health status, familiarity with psychometric tests, exposure to television as a child, motivation, and parental child-rearing practices.

In the present study, the disappearance of a decline in Verbal IQ with age when the age groups were balanced on education and when education was controlled in multiple regression analysis, gives strong support to the notion that mean Verbal IQs earned by the seven age groups are indeed related to differences in the number of years of formal schooling for each group. Like Green's (1969) study, this WAIS-R study appears "to have considerable internal validity in the sense of identifying actual causative factors for age differences in intelligence" (Kausler, 1982, p. 72). However, the failure of an educational control to alter substantially the decline in Performance IQ within the 20 to 74 year range indicates that age (and/or unknown cohort differences among the samples) and <u>not</u> education, is the main causative factor in producing the declining Performance IQs.

As Kausler (1982) reiterates,

> high internal validity means high generalizability of the causative factors identified in that study, that is, the causative role played

> by these factors is not restricted to the specific samples studied nor is it restricted to the specific populations sampled in that study. The implication is that it applies to all populations of people that exhibit variation in these causative factors. (p. 72)

Therefore, the relationships among age, education, and IQ found in this study are likely generalizable to future samples of adults. One might legitimately predict that the age to age decline in Verbal IQ will become smaller in future restandardizations of the WAIS-R, as educational differences become increasingly less disparate from generation to generation, and the decline should disappear if educational differences disappear.

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Table 1

Mean Sums of Scaled Scores, and Percents in Different Educational Categories, for Seven WAIS-R Standardization Age Groups

Age Group	Mean Sum of Scaled Scores: Verbal	Performance	Full Scale	Percentage of Adults with: 11 or less years of schooling	High school graduate	One or more years of college
20-24	58.6	51.1	109.8	17.0	43.5	39.5
25-34	61.4	49.9	111.3	17.0	39.3	43.7
35-44	57.5	45.3	102.7	26.0	42.4	31.6
45-54	58.1	42.1	100.2	34.4	40.0	25.6
55-64	55.6	38.2	93.8	43.7	36.9	19.4
65-69	53.5	33.8	87.4	55.0	25.6	19.3
70-74	51.5	30.6	82.1	60.0	23.8	16.2

Note: These data are from Wechsler (1981, Tables 5 and 7).

Table 2

Multiple Regression Analysis for the Prediction of WAIS-R IQs and Scaled Scores, Using Age as a Predictor (With and Without a Control for Education) for Ages 20-74 Years (*N* = 1480)

	Age as Sole Predictor		Age as Second Predictor (After Education)			
WAIS-R Criterion	R^2	*F*	Educ R^2	Educ & Age R^2	Increment in R^2	*F* of Increment
Sum of Scaled Scores						
Verbal	.031	47.98**	.451	.454	.003	8.39*
Performance	.282	578.99**	.329	.456	.127	343.36**
Full Scale	.134	228.03**	.455	.475	.020	58.00**
Verbal Subtests						
Information	.010	15.36**	.347	.358	.0111	26.10**
Digit Span	.032	48.68**	.214	.215	.001	0.87
Vocabulary	.008	11.35**	.370	.386	.016	39.71**
Arithmetic	.017	25.13**	.279	.282	.003	6.17
Comprehension	.011	16.37**	.310	.318	.008	18.10**
Similarities	.072	114.25**	.330	.336	.006	12.80**

Table 2 Continued

	Age as Sole Predictor		Age as Second Predictor (After Education)			
	R^2	F	Educ R^2	Educ & Age R^2	Increment in R^2	F of Increment
Performance Subtests						
Picture Completion	.144	249.04**	.212	.268	.056	112.75**
Picture Arrangement	.175	313.77**	.207	.286	.079	161.50**
Block Design	.172	306.60**	.243	.312	.069	146.73**
Object Assembly	.167	296.30**	.152	.238	.086	166.19**
Digit Symbol	.292	607.97**	.289	.433	.144	373.35**

*$p < .01$

**$p < .001$

Table 3

Mean WAIS-R Verbal, Performance, and Full Scale Sums of Scaled Scores for Adults Completing Different Numbers of Years of Schooling, by Age

	Age Group						
Years of Schooling	20-24	25-34	35-44	45-54	55-64	65-69	70-74
Verbal Scale							
0-8	41.6	31.9	37.3	41.8	42.3	42.4	43.0
9-11	51.1	50.8	45.8	51.4	52.7	52.2	51.1
12	55.5	57.6	58.2	60.0	59.9	59.4	55.6
13-15	65.0	67.7	63.6	65.4	65.0	62.2	66.0
16+	69.5	74.3	72.8	74.2	75.3	73.8	72.9
Weighted mean	59.5	61.4	60.2	62.4	62.8	61.6	60.6
Performance Scale							
0-8	37.0	33.1	31.9	31.0	28.9	28.3	27.7
9-11	47.7	44.0	38.0	40.2	37.6	35.8	30.8
12	49.5	47.6	46.1	43.8	42.1	36.0	31.7
13-15	54.3	53.6	50.0	44.4	42.6	37.4	35.9
16+	58.7	57.2	53.7	50.2	47.9	41.8	38.0
Weighted mean	51.8	49.9	47.0	44.4	42.4	37.2	33.7

Table 3 Continued

	Years of Schooling	Age Group 20-24	25-34	35-44	45-54	55-64	65-69	70-74
Full Scale								
	0-8	78.6	65.0	69.2	72.8	71.2	70.7	70.7
	9-11	98.8	94.8	83.7	91.6	90.3	88.0	81.8
	12	105.0	105.3	104.4	103.8	101.9	95.5	87.3
	13-15	119.2	121.2	113.5	109.8	107.7	99.6	101.9
	16+	128.2	131.5	126.5	124.4	123.2	115.6	110.9
Weighted mean		112.2	111.3	107.2	106.8	105.1	98.9	94.3

Note. Weighted means were obtained by using as weights the proportions of adults in each educational category at ages 25-34 years.

Table 4

Mean IQs of Adults at Seven Age Levels, Based on Norms for Ages 25-34, with and without a Control for Educational Level

Age group	Based on age 25-34 years	Based on age 25-34 years, education controlled	Change
Verbal IQ			
20-24	95.6	96.5	+0.9
25-34	98.4	98.4	0.0
35-44	94.5	97.2	+2.7
45-54	95.1	99.4	+4.3**
55-64	92.6	99.8	+7.2**
65-69	91.0	98.6	+7.6**
70-74	89.5	97.6	+8.1**
Performance IQ			
20-24	101.1	101.8	+0.7
25-34	98.9	98.9	0.0
35-44	93.3	95.0	+1.7
45-54	89.2	92.4	+3.2
55-64	84.2	89.8	+5.6*
65-69	78.8	82.4	+3.5*
70-74	75.6	78.7	+3.1

Table 4 Continued

Age group	Based on age 25-34 years	Based on age 25-34 years, education controlled	Change
Full Scale IQ			
20-24	97.2	98.8	+1.6
25-34	98.2	98.2	0.0
35-44	93.5	95.8	+2.3
45-54	91.8	95.6	+3.8*
55-64	87.6	94.8	+7.2**
65-69	84.4	91.3	+6.9**
70-74	81.7	87.9	+6.2**

**$p < .01$

*$p < .05$

Table 5

Summary of Tukey HSD Comparisons between Pairs of Age Groups on the Verbal, Performance, and Full Scales, Both with and without a Control for Education

Verbal without Control for Education

Age Group	25-34	20-24	45-54	35-44	55-64	65-69	70-74
Mean	98.4	95.6	95.1	94.5	92.6	91.2	89.5

Tukey HSD = 4.44

Performance without Control for Education

Age Group	20-24	25-34	35-44	45.54	55.64	65-69	70-74
Mean	101.1	98.9	93.3	89.2	84.2	78.8	75.6

Tukey HSD = 4.50

Performance with Control for Education

Age Group	20-24	25-34	35-44	45-54	55.64	65-69	70-74
Mean	101.8	98.9	95.0	92.4	89.8	82.4	78.7

Tukey HSD = 4.50

Table 5 Continued

Full Scale without Control for Education							
Age Group	25-34	20-24	35-44	45-54	55-64	65-69	70-74
Mean	98.3	97.4	93.7	92.1	87.8	84.4	82.0

Tukey HSD = 4.63

Full Scale with Control for Education							
Age Group	20-24	25-34	35-44	45-54	55-64	65-69	70-74
Mean	99.1	98.3	96.1	95.8	95.1	91.4	88.2

Tukey HSD = 4.52

Note: Pairwise comparisons are not presented for the Verbal sums of scaled scores after equating for educational level because the F for the age main effect did not reach statistical significance in that analysis. A common line under two or more sample means indicates they are not significantly different at the .05 level.

Table 6

Mean Verbal Scaled Scores of Adults at Seven Age Levels, with and without a Control for Education Level

Age Group	Information			Digit Span			Vocabulary			Arithmetic			Comprehension			Similarities		
	S.S.	Wtd. S.S.	Chg.	S.S.	Wtd. S.S.	Chg.	S.S.	Wtd. S.S.	Chg.	S.S.	Wtd. S.S.	Chg.	S.S.	Wtd. S.S.	Chg.	S.S.	Wtd. S.S.	Chg.
20-24	9.7	9.9	+0.2	10.0	10.1	+0.1	9.5	9.7	+0.2	9.8	9.9	+0.1	9.7	9.9	+0.1	9.9	10.0	+0.1
25-34	10.4	10.4	-	10.0	10.0	-	10.3	10.3	-	10.2	10.2	-	10.2	10.2	-	10.2	10.2	-
35-44	9.6	10.0	+0.4	9.5	9.9	+0.4	9.8	10.3	+0.5	9.5	10.0	+0.5	9.9	10.4	+0.5	8.2	9.6	+0.4
45-54	10.0	10.8	+0.8	9.5	10.1	+0.6	9.8	10.6	+0.8	9.8	10.4	+0.6	9.9	10.6	+0.7	9.1	9.9	+0.8
55-64	9.6	10.9	+1.4	9.2	9.9	+0.7	9.5	11.0	+1.5	9.2	10.4	+1.2	9.7	11.0	+1.3	8.4	9.6	+1.2
65-69	9.4	10.9	+1.5	8.6	9.4	+0.8	9.2	10.7	+1.5	9.0	10.0	+1.0	9.3	11.0	+1.7	8.1	9.5	+1.4
70-74	8.9	10.4	+1.5	8.4	9.4	+1.0	9.2	11.1	+1.9	8.8	10.3	+1.5	8.8	10.4	+1.6	7.3	9.0	+1.7

Note. S.S. = Scaled score; Wtd. S.S. = Weighted scaled score; Chg. = Change. Weighted mean scaled scores were obtained by using as weights the proportions of adults in each educational category at ages 25-34 years.

Table 7

Mean Verbal Scaled Scores of Adults at Seven Age Levels, with and without a Control for Education Level

Age Group	Picture Completion			Picture Arrangement			Block Design			Object Assembly			Digit Symbol		
	S.S.	Wtd. S.S.	Chg.	S.S.	Wtd. S.S.	Chg.	S.S.	Wtd. S.S.	Chg.	S.S.	Wtd. S.S.	Chg.	S.S.	Wtd. S.S.	Chg.
20-24	10.2	10.3	+0.1	10.0	10.2	+0.2	10.3	10.3	0.0	10.2	10.3	+0.2	10.4	10.5	+0.1
25-34	10.2	10.2	-	10.0	10.0	-	9.8	9.8	-	10.0	10.0	-	9.9	9.9	-
35-44	9.2	9.7	+0.5	9.1	9.4	+0.3	8.9	9.3	+0.4	9.1	9.4	+0.3	9.0	9.4	+0.4
45-54	8.5	9.0	+0.5	8.5	9.0	+0.5	8.6	9.1	+0.5	8.4	8.7	+0.3	8.0	8.5	+0.5
55-64	8.1	9.0	+0.9	7.8	8.8	+1.0	7.7	8.4	+0.7	7.7	8.4	+0.7	6.9	7.7	+0.8
65-69	7.3	8.1	+0.8	6.8	7.4	+0.6	7.0	7.8	+0.8	7.0	7.4	+0.4	5.8	6.6	+0.8
70-74	6.6	7.4	+0.8	6.1	6.6	+0.5	6.4	7.2	+0.8	6.7	7.1	+0.4	4.9	5.5	+0.6

Note. S.S. = Scaled score; Wtd. S.S. = Weighted scaled score; Chg. = Change. Weighted mean scaled scores were obtained by using as weights the proportions of adults in each educational category at ages 25-34 years.

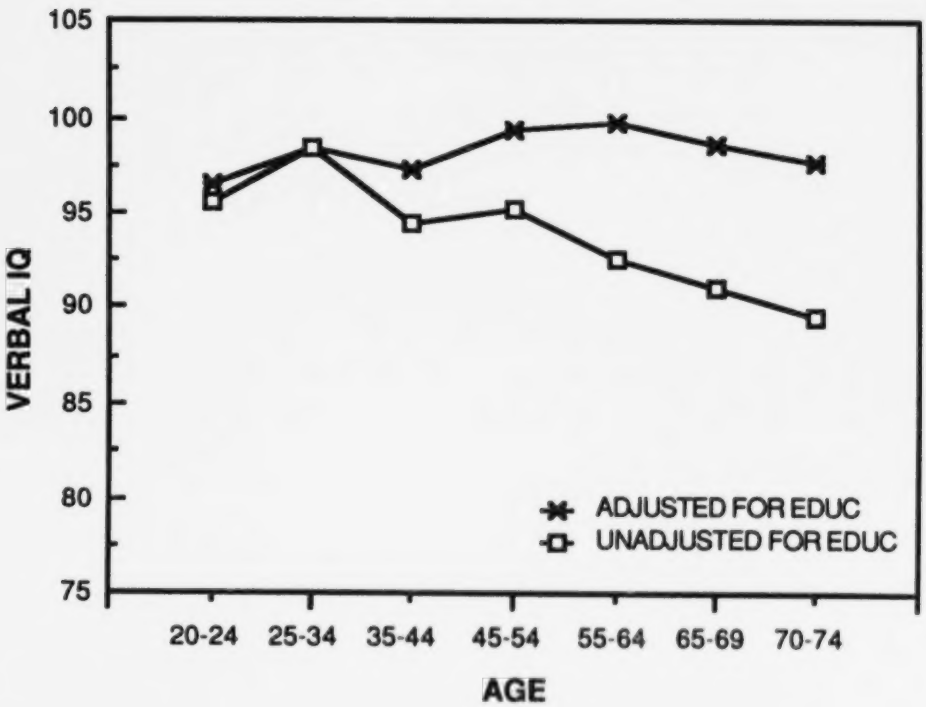

Figure 1. Change in Verbal IQ, across the 20-74 year age range,both with and without a control for education. (All IQs are based on norms for 25-34 year olds.)

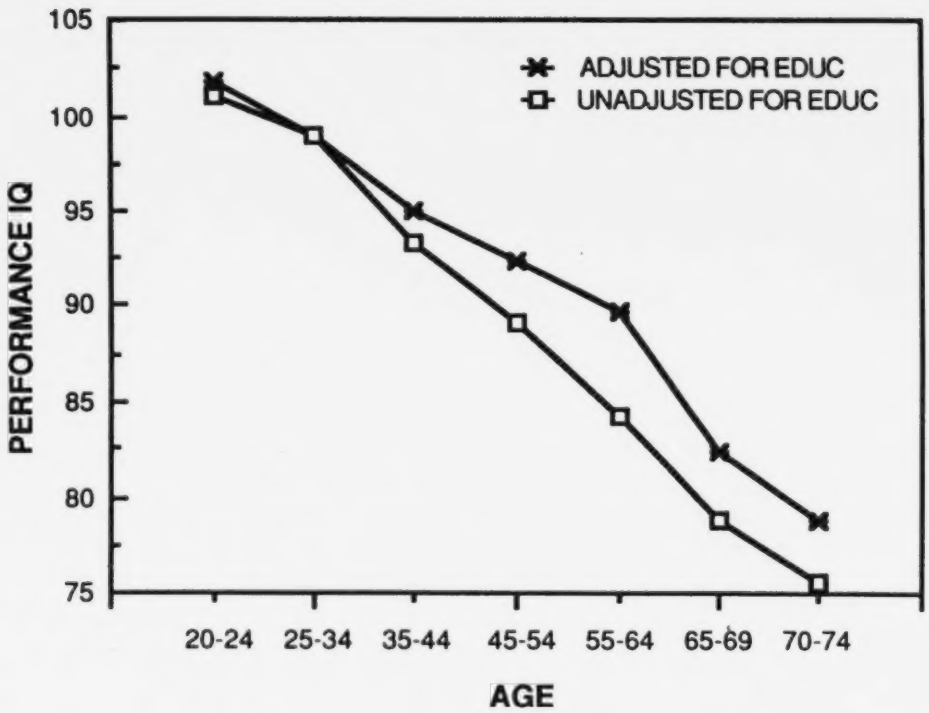

Figure 2. Change in Performance IQ, across the 20-74 year age range, both with and without a control for education. (All IQs are based on norms for 25-34 year olds.)

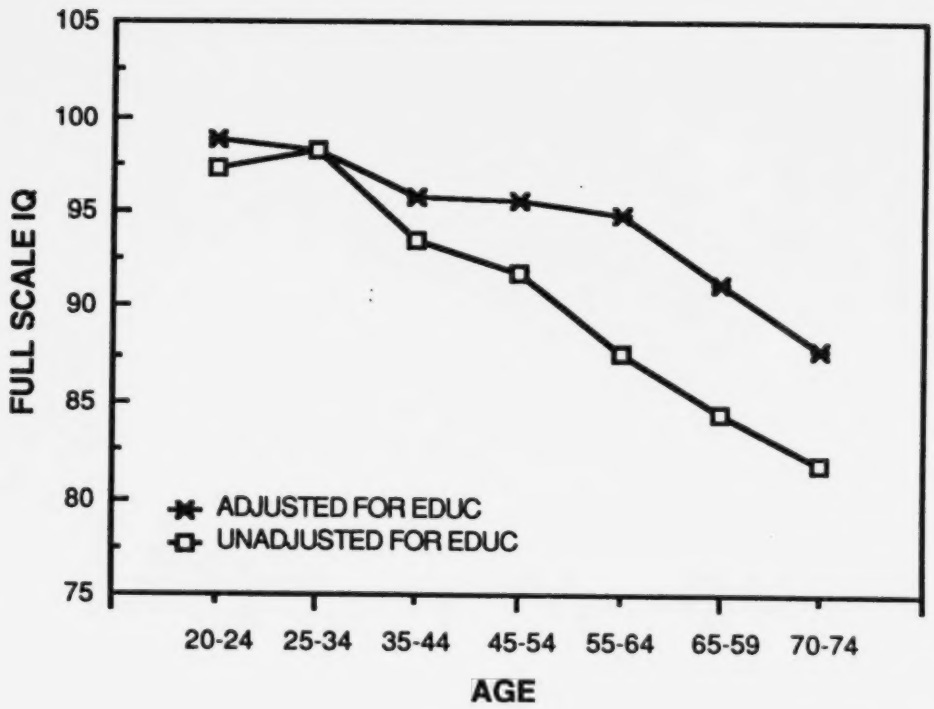

Figure 3. Change in Full Scale IQ, across the 20-74 year age range, both with and without a control for education. (All IQs are based on norms for 25-34 year olds.)

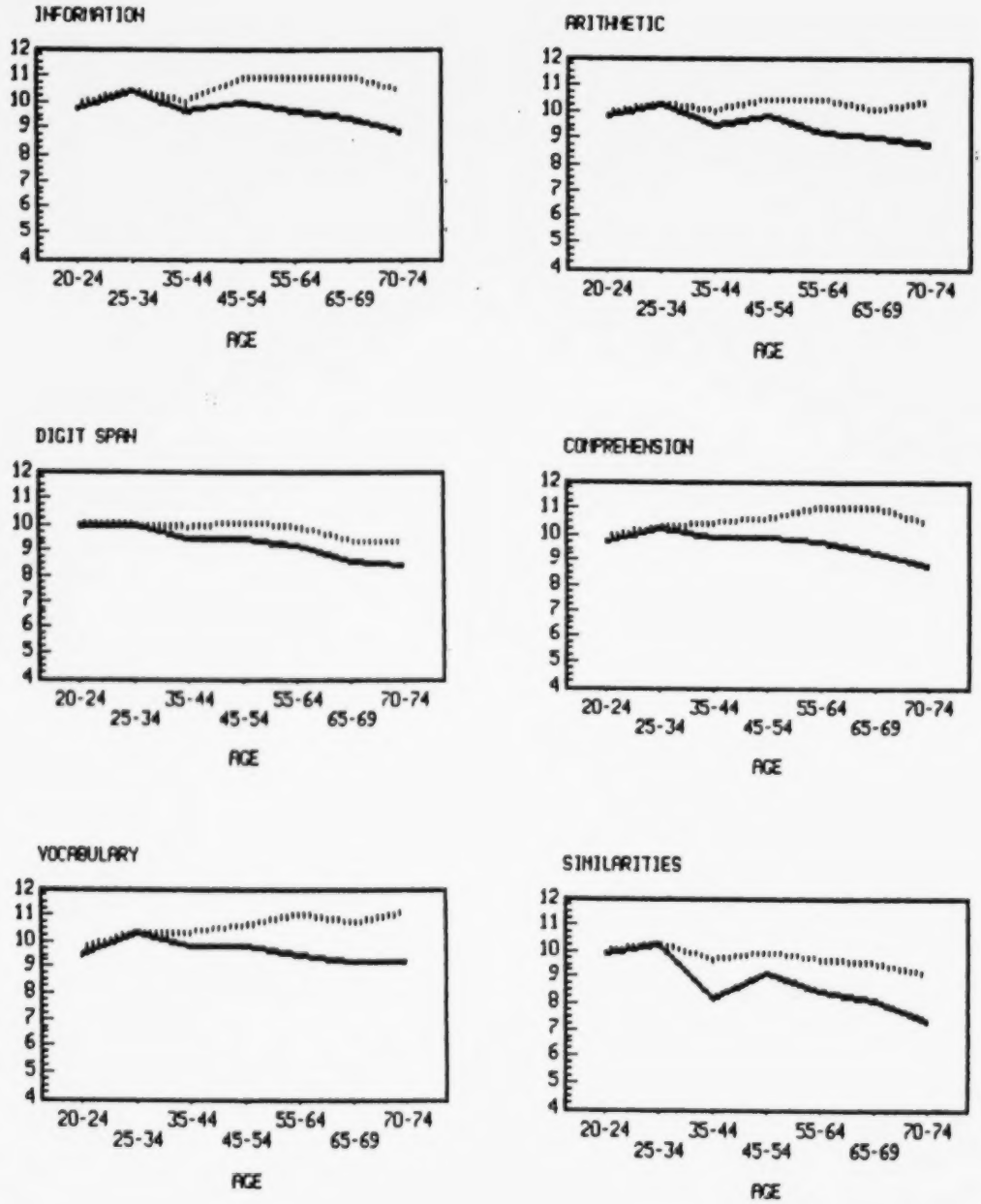

Figure 4. Change in WAIS-R Verbal Subtest Scaled Scores across the 20-74 year age range, both with and without a control for education.

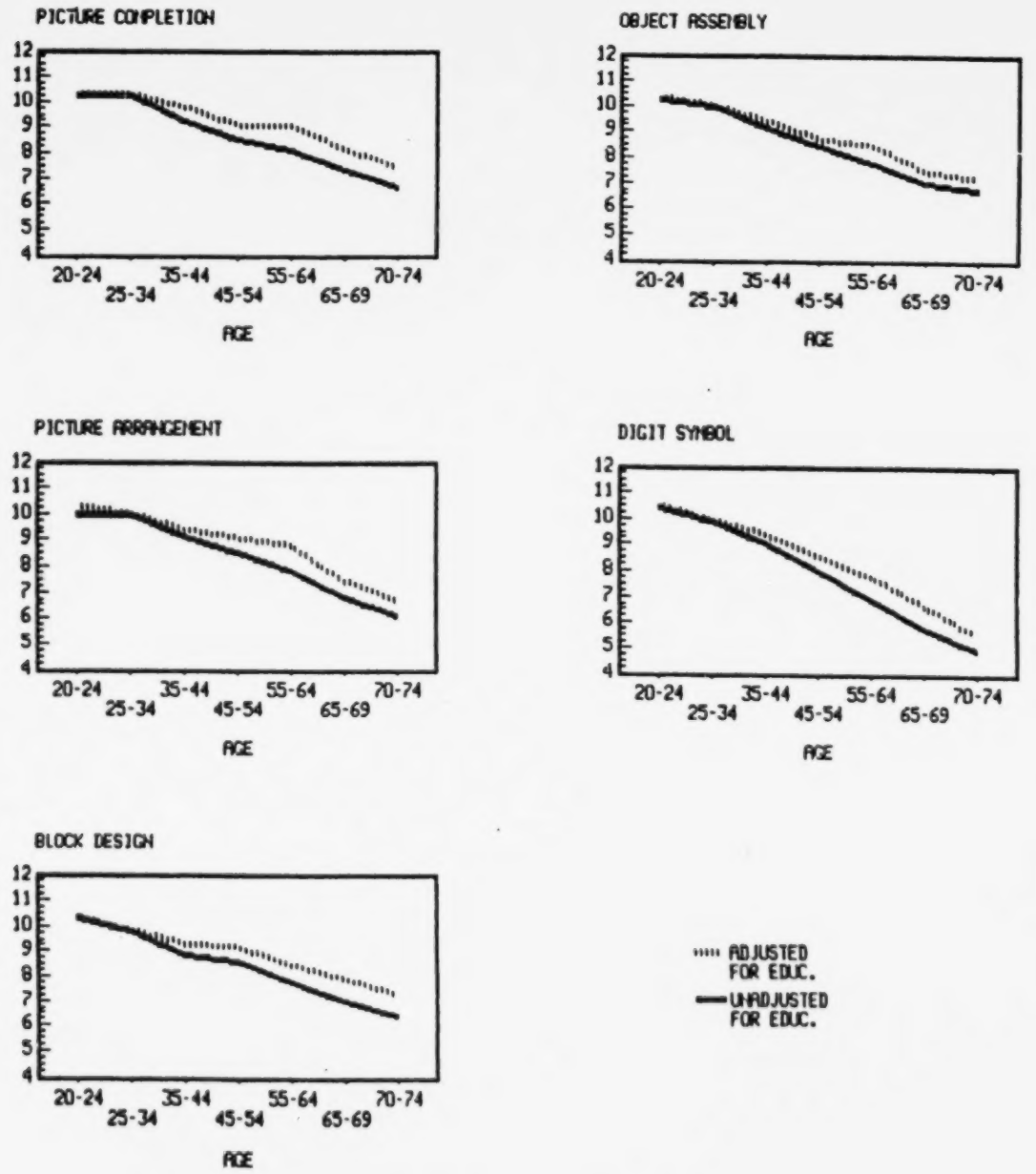

Figure 5. Change in WAIS-R Performance Subtest Scaled Scores across the 20-74 year age range, both with and without a control for education.